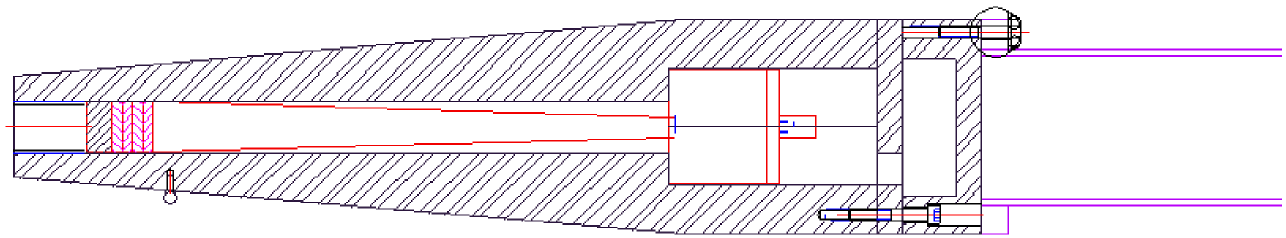
A neutron bang-time diagnostic for indirectly driven experiments on Omega



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LA-UR 99-6044

A neutron bang-time diagnostic for indirectly driven experiments on Omega

A detector for measuring the average time of neutron emission from an inertial confinement fusion target ("bang time") has been designed, fabricated, and installed on the Omega laser facility. The detector is based on a plastic scintillator with sub-nanosecond decay time and a commercial microchannel plate photomultiplier tube. This detector is designed for yields of 5×10^7 DD neutrons and higher, and is shielded to prevent interference from hard x-rays generated in the target. Timing characterization will be done with x-rays. To prevent x-ray detection in the microchannel plate from affecting the timing results, the scintillator is coupled to the PMT by a 30-cm-long lead glass light guide. Examples of data from characterization and implosion experiments will be presented.

This work was performed under the auspices of the U. S. Department of Energy by the Los Alamos National Laboratory under contract No. W-7405-Eng-36.

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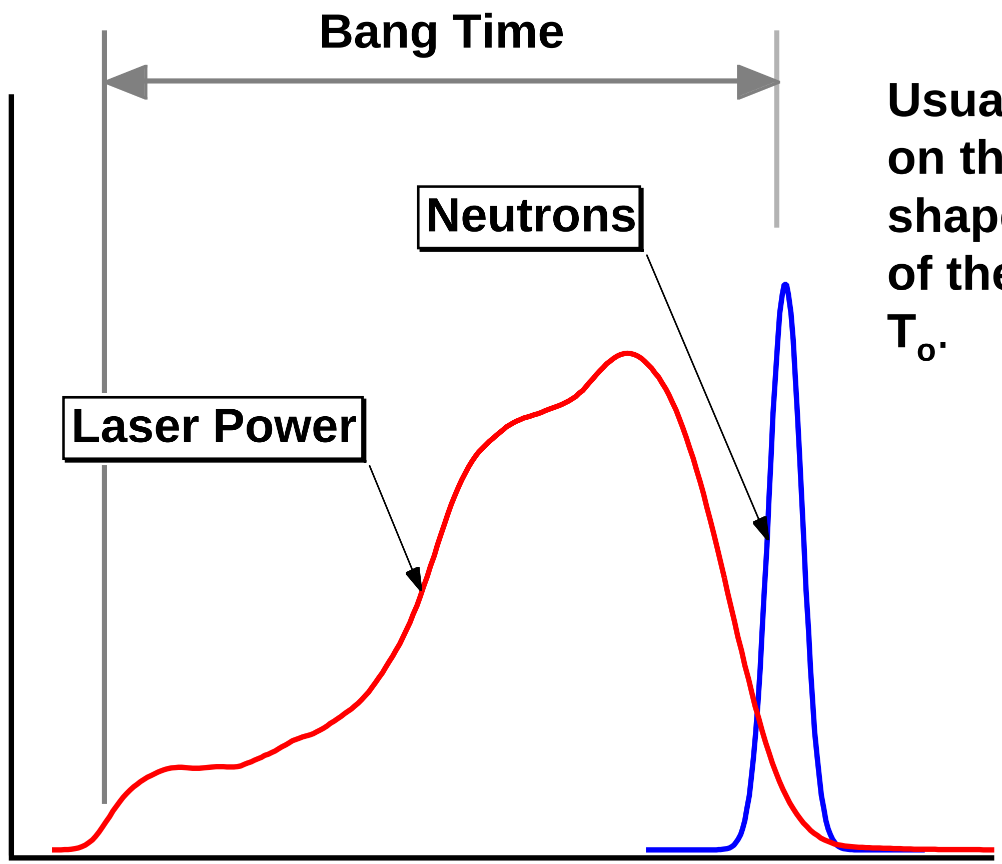
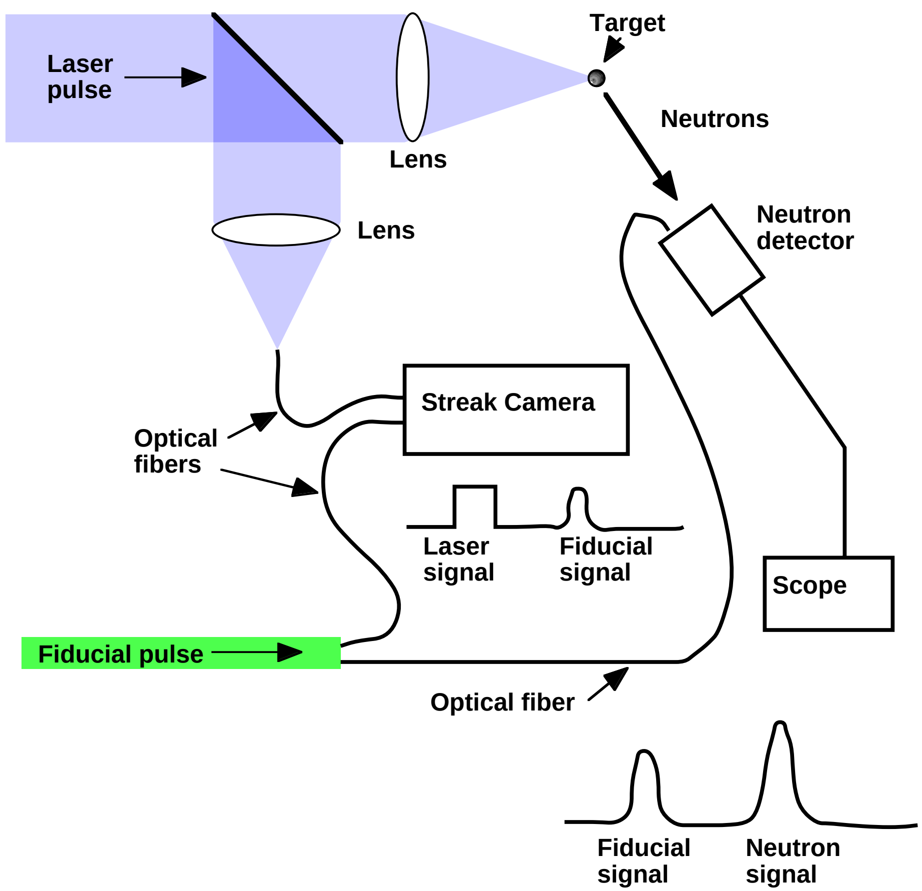
Bang time is defined as the average neutron emission time relative to some feature of the laser pulse shape



Usually we use the 50% point on the leading edge or, for shaped pulses, the 50% point of the "foot" of the pulse as T_o.

Measuring the implosion time requires relating the time of neutron emission to the laser pulse



$$t_n - t_l = \Delta t_{nf} - \Delta t_{lf} + \Delta t_{cal} - \Delta t_{tof}$$

where:

Δt_{nf} = neutron to fidu time

Δt_{lf} = laser to fidu time

Δt_{cal} = calibration number

Δt_{tof} = radiation time-of-flight

R. A. Lerche *et al*, Rev. Sci. Instrum. 59, 1697 (1988).

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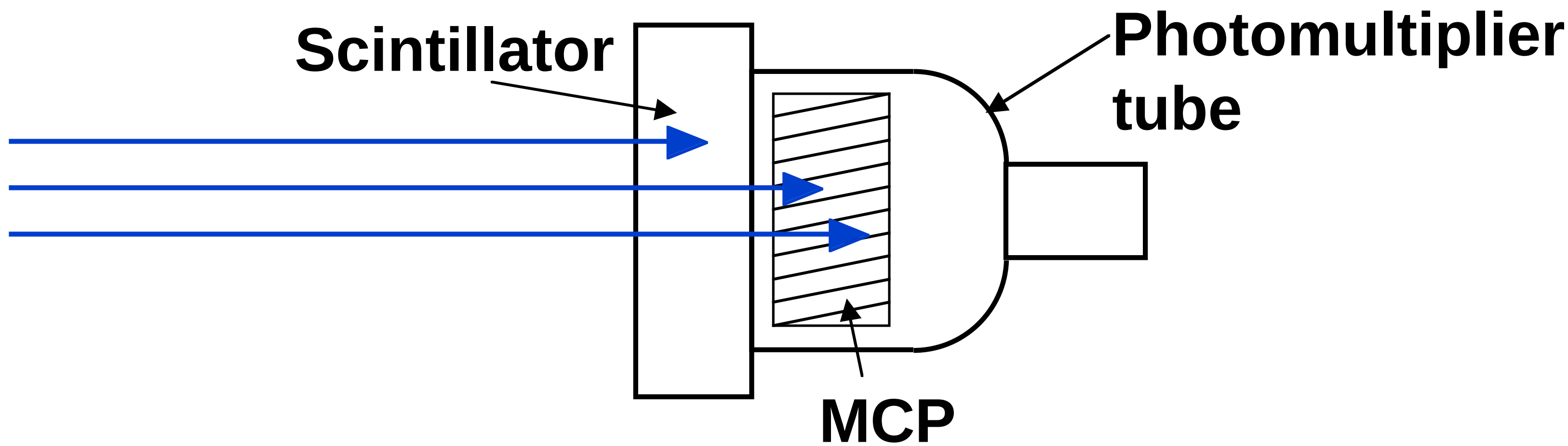
Calibration of the system is performed with x-rays

Using a short pulse at high intensity, a pulse of x-rays can be produced at a known time. This establishes the overall timing of the system.

The known distance of the detector is then used to determine the additional flight time for DD or DT neutrons which is then subtracted to yield a bang time.

So far, the excellent shielding has prevented us from seeing hard x-rays. Plans for the near future include running the system with the front shielding plug removed.

Previous systems have placed the scintillator in contact with the MCP-PMT



X-rays used for calibration might pass through the scintillator interacting directly in the MCP.

Since electrons in the MCP travel much slower than the x-rays, photons which interact deep in the MCP produce a signal earlier than those that interact in the scintillator to produce light, since photoelectrons produce electrons that must travel the entire distance of the MCP.

Thus, an inaccurate calibration is possible.

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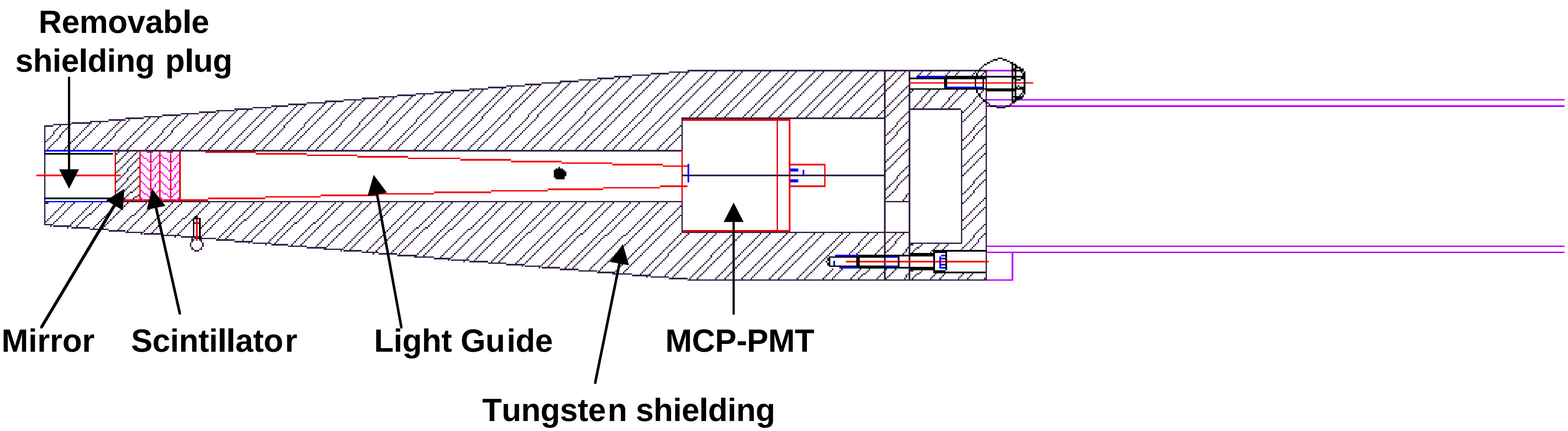
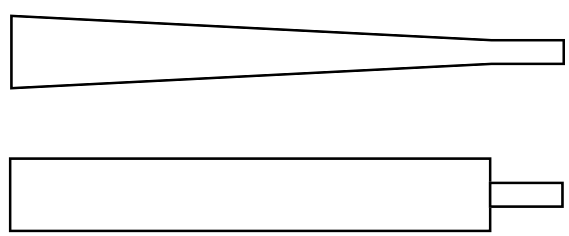
The detector consists of a well-shielded microchannel plate PMT connected to a scintillator with a lead-glass light guide





Originally, a tapered light guide was planned for joining the 1 in scintillator to the 1 cm photocathode, but modeling showed that it was only marginally better than two glass rods cemented glass rods to make the transition.

The light guide ensures that no x-rays can interact directly with the MCP on calibration shots.

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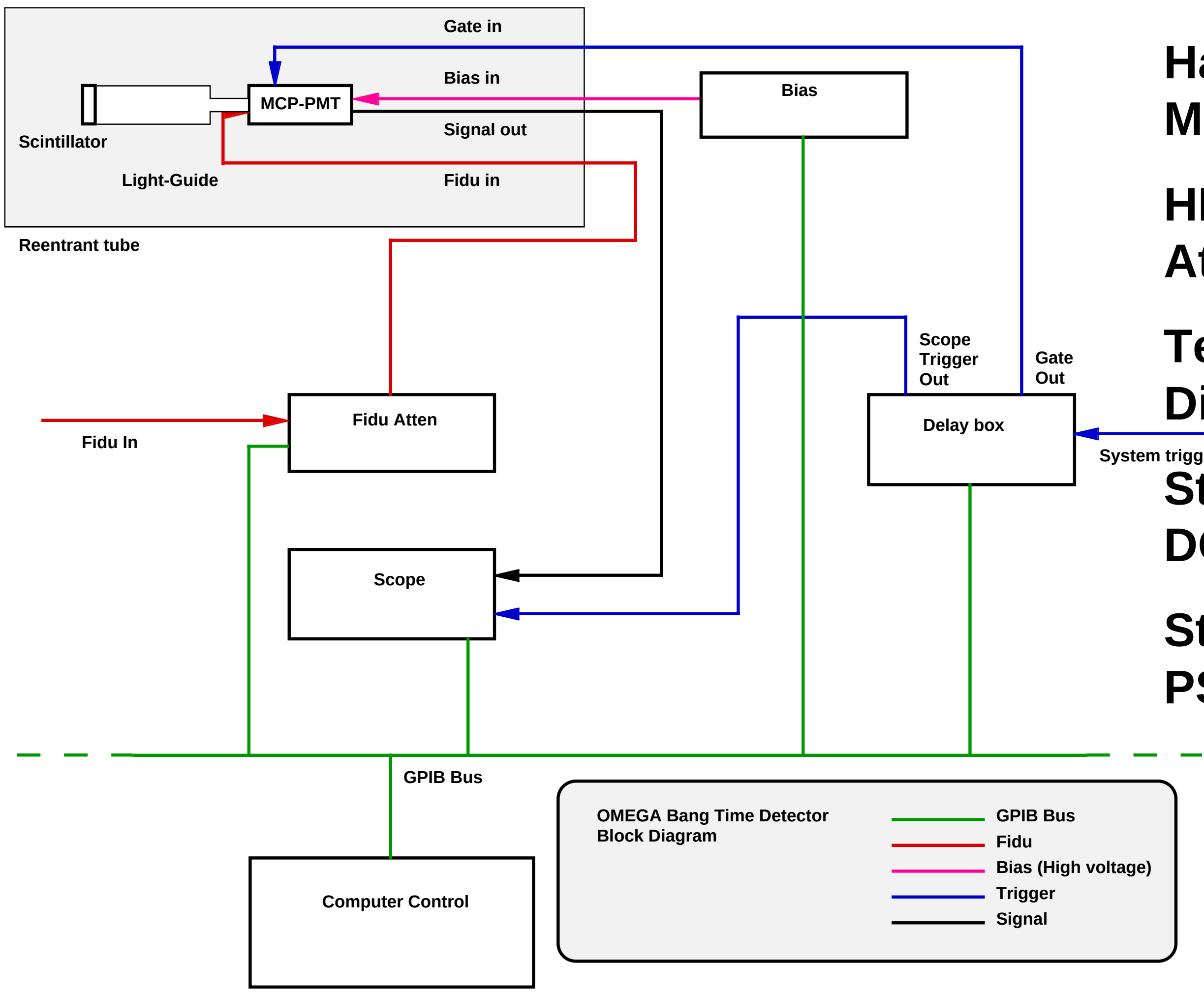
The system was designed to use GPIB-controllable parts so that the system can be automated



Hamamatsu R5916U-50 MCP-PMT

HP 8156A Optical Attenuator

Tektronix TDS684B Digitizer

Stanford Research DG535 Delay Generator

Stanford Research PS350 Bias Supply

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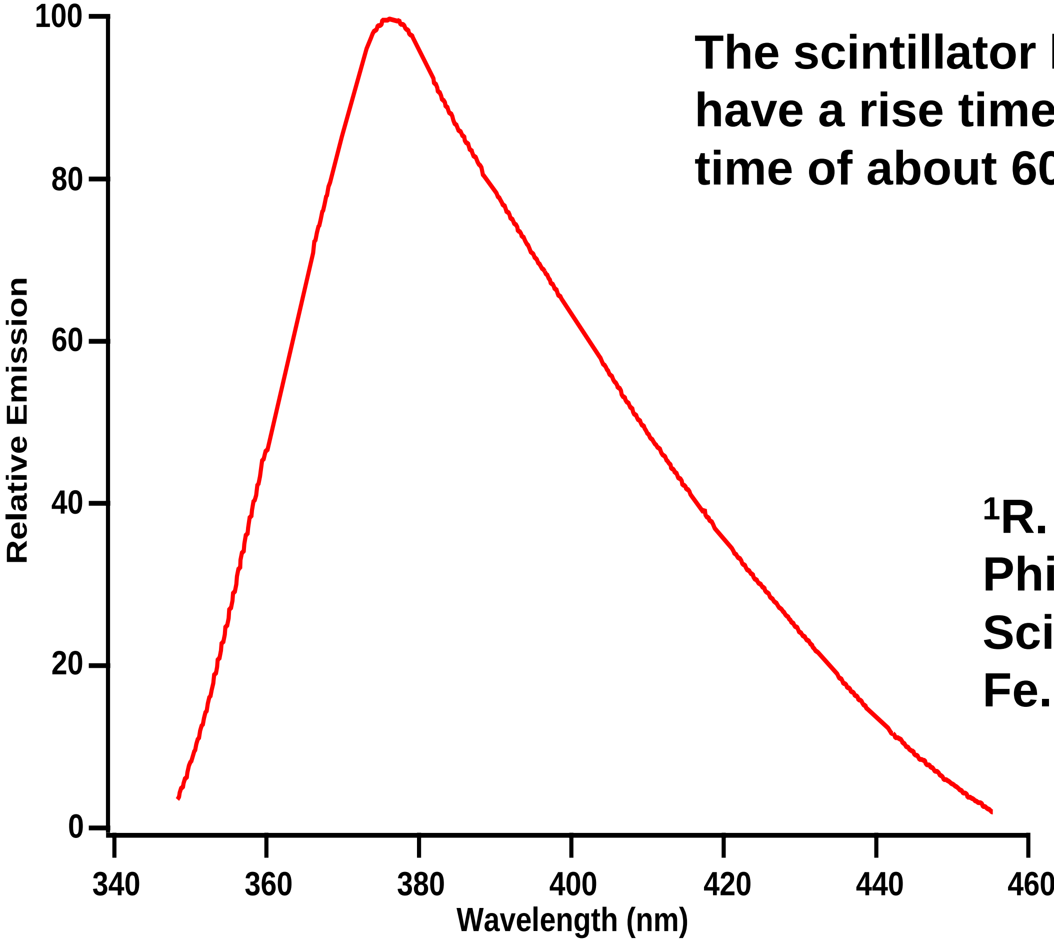
The detector utilizes BC-422 Q scintillator, which emits in the near UV



The scintillator has been shown to have a rise time[1] < 20 ps and a decay time of about 600 ps.

[1]R. A. Lerche and D. W. Phillion, 1991 IEEE Nuclear Science Symposium, Santa Fe.

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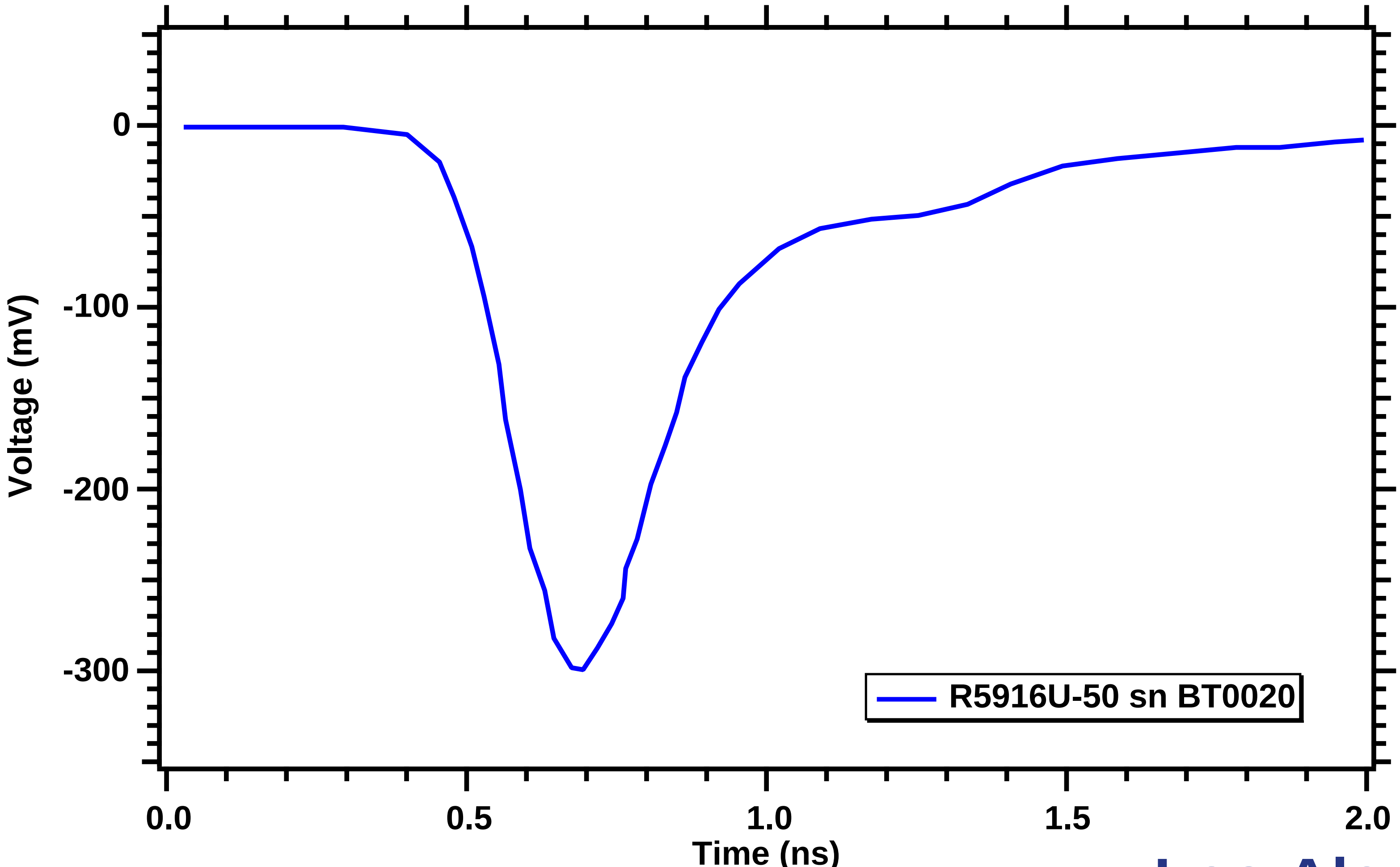
A microchannelplate photomultiplier tube with a 300 ps FWHM was used



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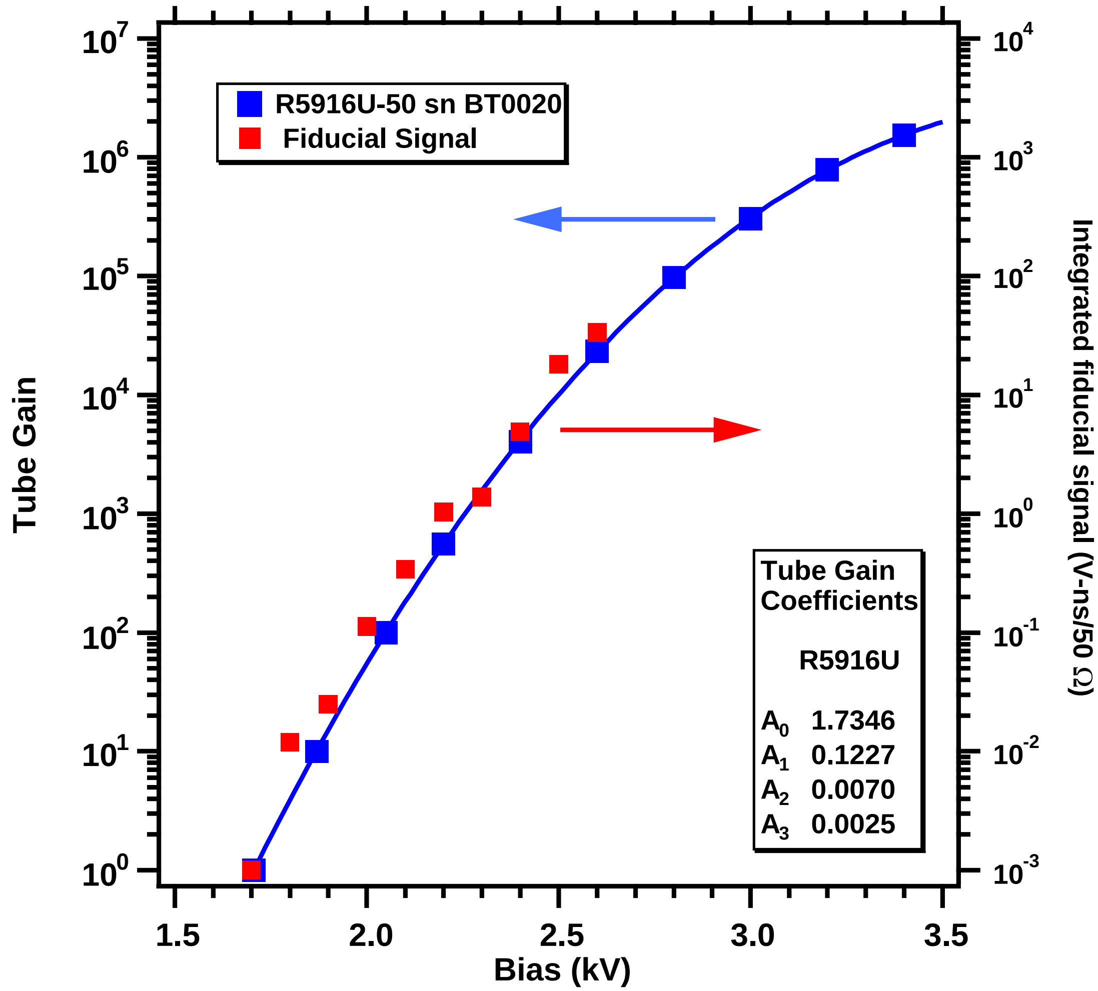
Tube gain can be varied over six orders of magnitude by changing the bias voltage



The blue points show the manufacturers gain characterization.

The red points show the integrated signal from the Omega fiducial as a function of bias voltage.

The gain can be fit by:

$$\log_{10} Gain = \sum_i A_i V^i$$

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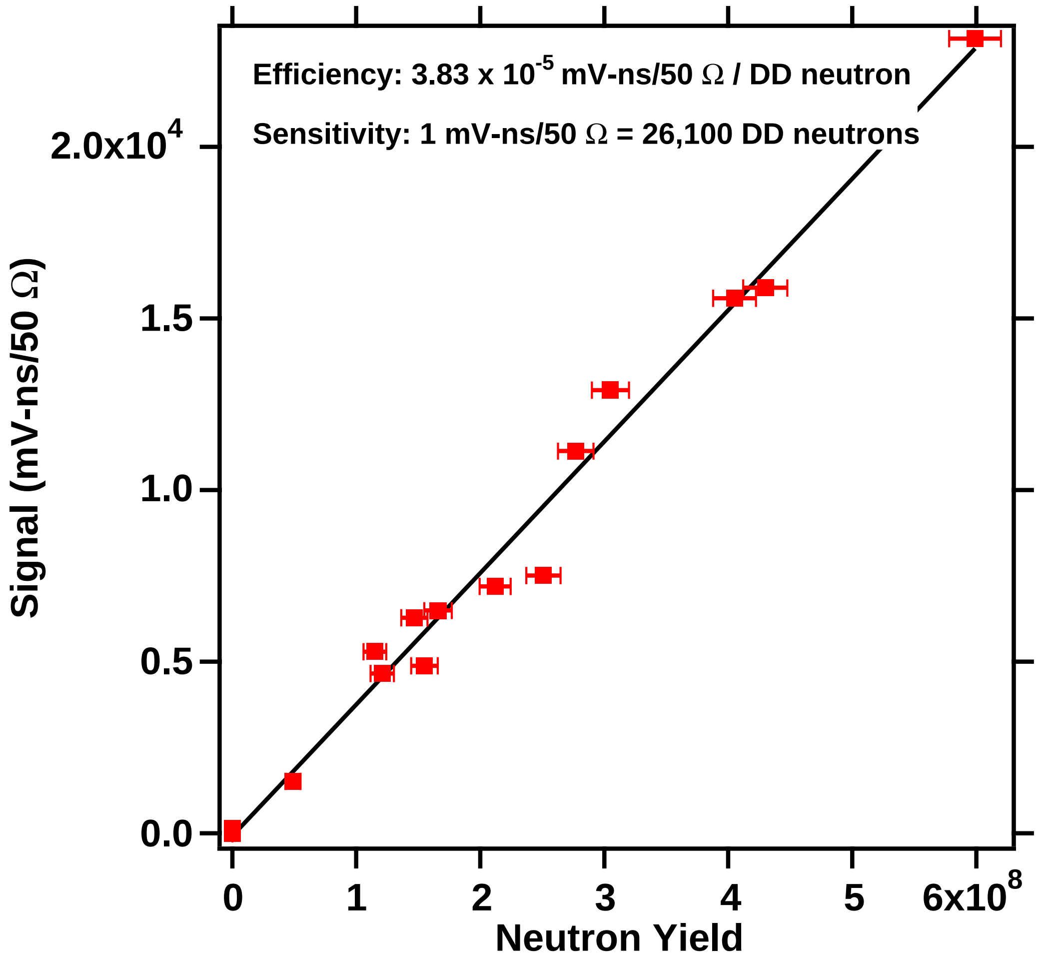
The efficiency of the system was determined by comparing the integrated signal to the neutron yield



Neutron yields provided by LLE

Data obtained on LLNL indirect drive shots courtesy of R. Turner

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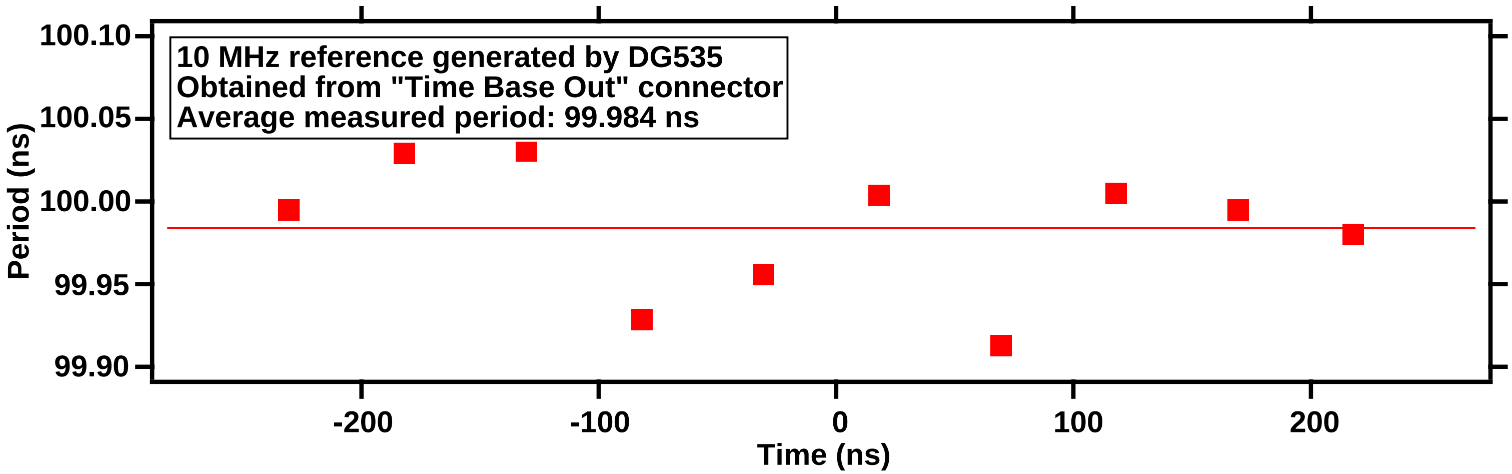
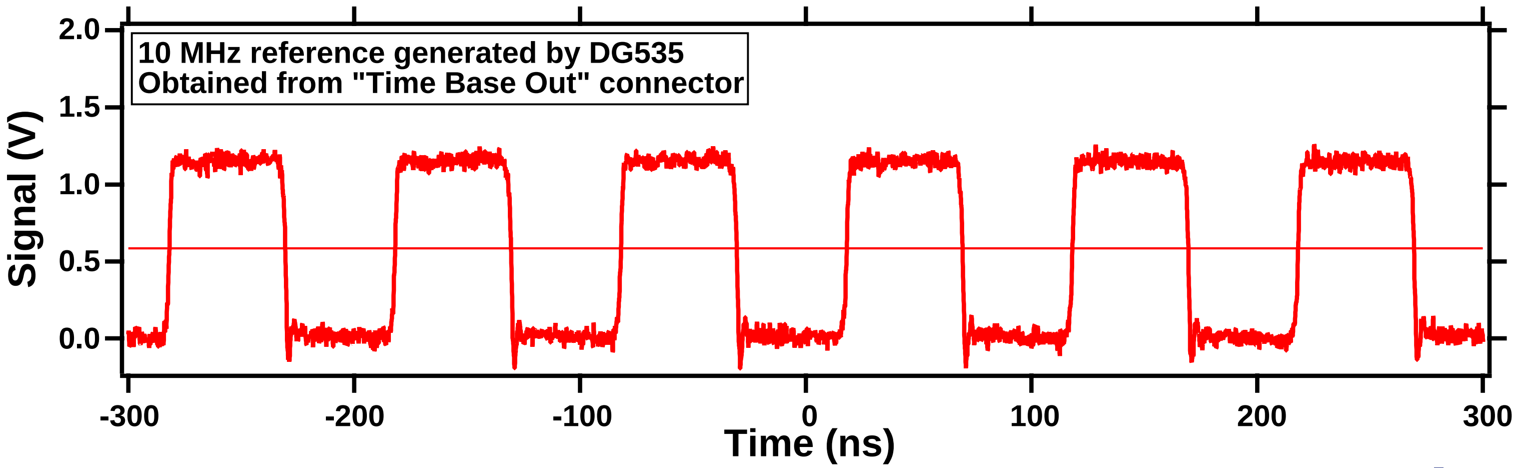
The time base of the digitizer has been checked using the 10 MHz output from the delay box and is good to 0.016%





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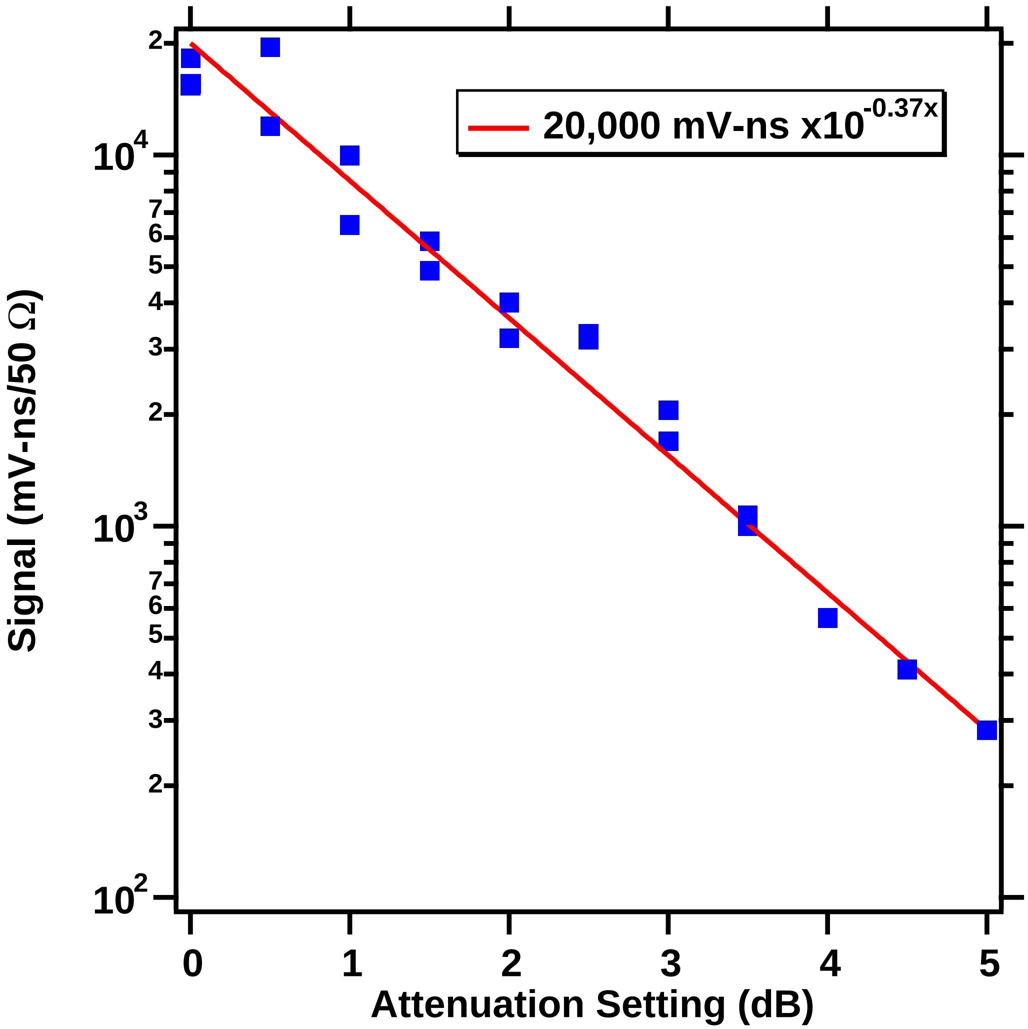
A programmable attenuator is used to match the fiducial height to the neutron signal



The attenuator is designed for 1200-1650 nm, and not the 530 nm where we use it.

Therefore, the attenuation does not agree with the setting, but may be calibrated.

At 0 dB setting, the fiducial is attenuated by a factor of 60 relative to bypassing the attenuator. Thus, some modification to the attenuator is desirable to allow the system to be used on higher yield experiments.

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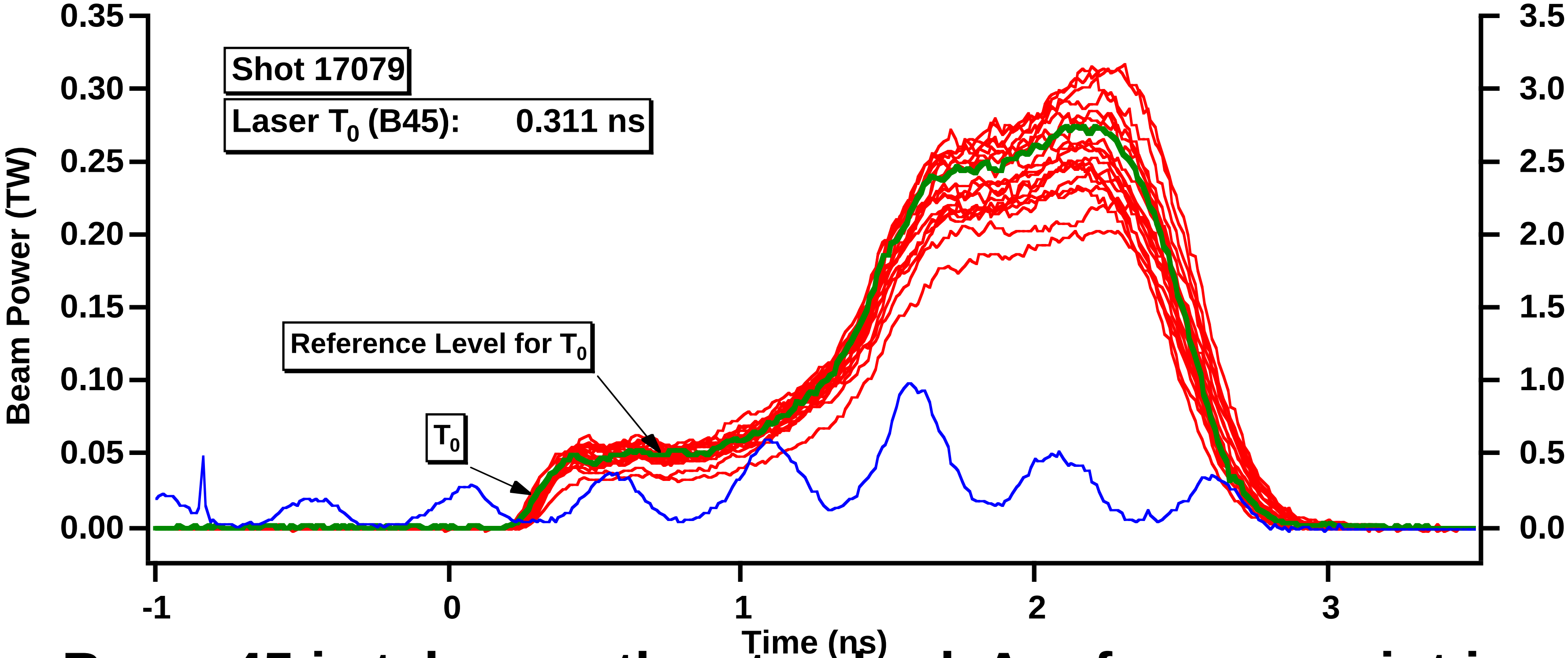
The bang time is referenced to the 50% point of the leading edge of the laser pulse



Beam 45 is taken as the standard. A reference point is chosen and T_o is found by proceeding earlier until the 50% point is found.

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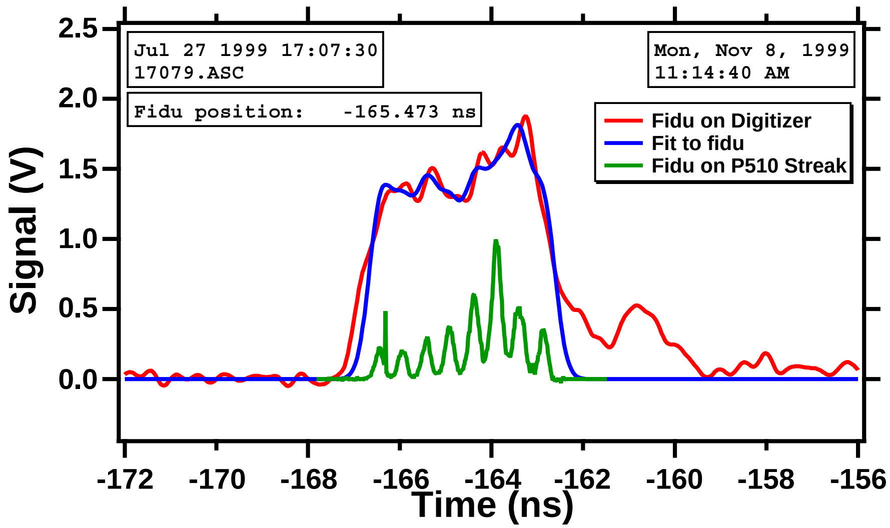
Good interpretation of the fiducial is important



We use the analysis of the fiducial provided by LLE and their definition of T_o, that is, T_o is defined to be 452.25 ps after the second peak in the pulse train.

The 50% point of the rise of the laser pulse is then referenced to that T_o point.

While the pulse train is convenient for streak camera based instruments, its interpretation for instruments with moderate time resolution (such as this one) is problematic. Better results would be obtained with a single Gaussian fiducial pulse.

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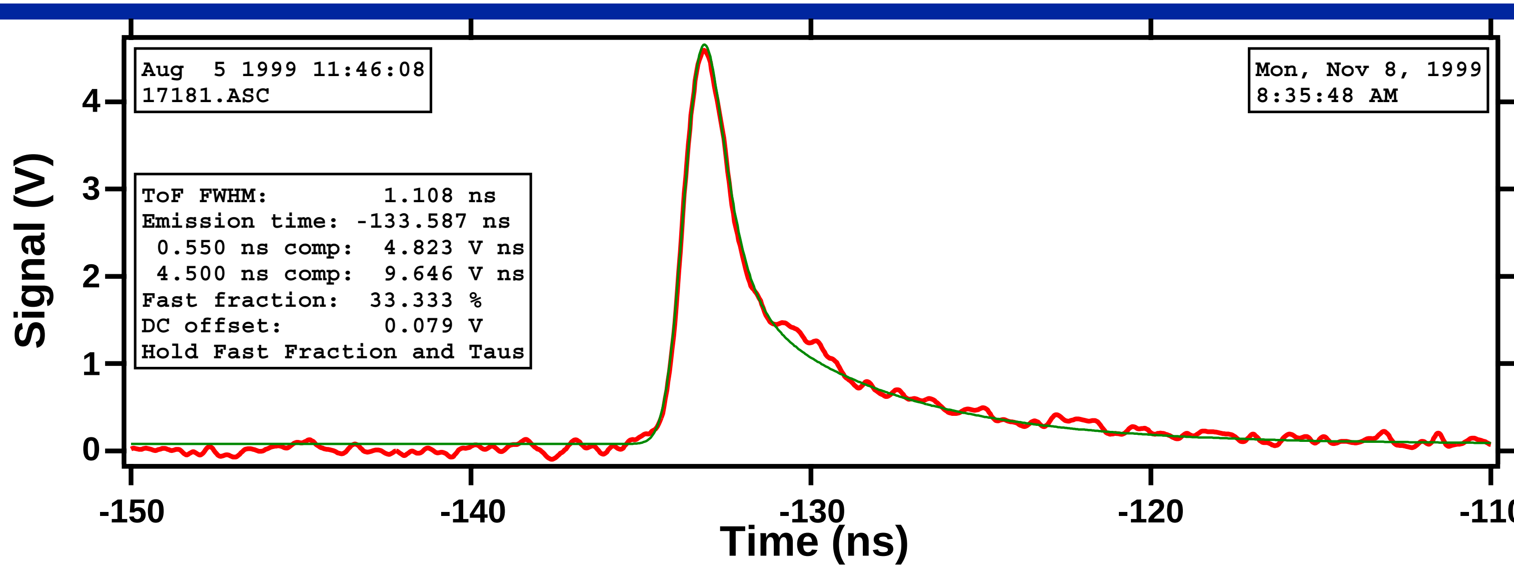
To perform the analysis of bang time data, one must fit the fiducial and the neutron signal



The neutron signal can be fit by the convolution of a Gaussian with the sum of two exponential decays [T. J. Murphy et al., Rev. Sci. Instrum. 68, 610 (1997)] which is given by:

$$h(t;\sigma,\tau_1,\tau_2) = \sum_i A_i \frac{\exp(-t/\tau_i)\exp(\sigma^2/2\tau_i^{\,2})}{2\tau_i}\left[1+\mathrm{erf}\left(\frac{t-\sigma^2/\tau_i}{\sqrt{2\sigma^2}}\right)\right]$$

We find that τ_1=0.55 ns, τ_2=4.5 ns, and $A_1/(A_1+A_2)$=1/3 produces a good fit.

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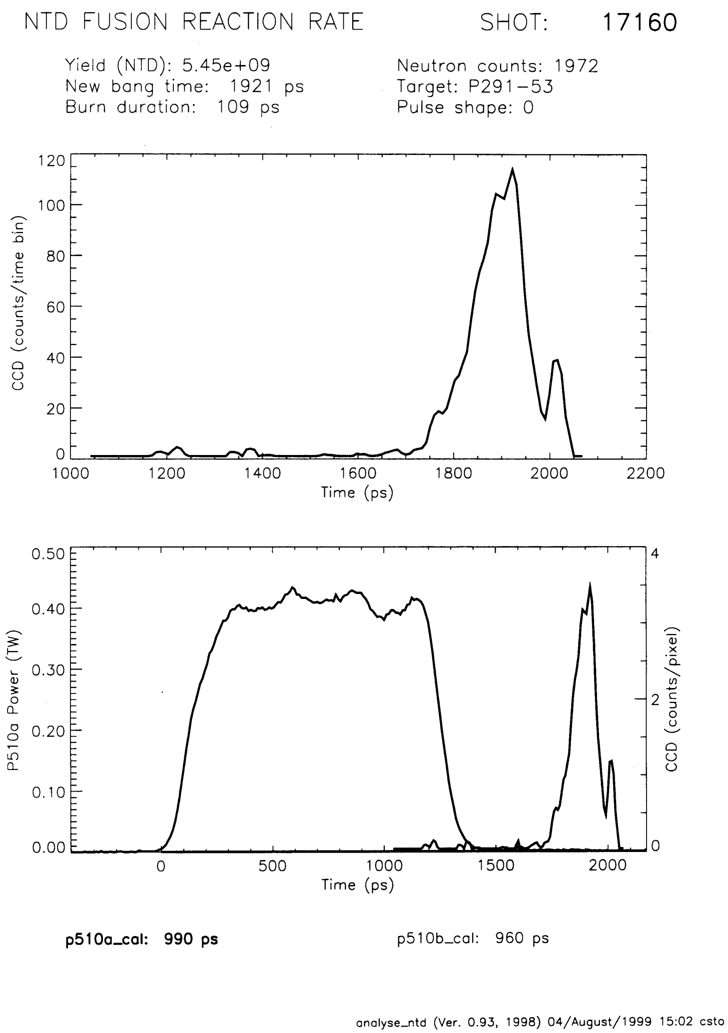
At higher yield, the system can be compared to LLNL's nTD to calibrate the system



This system consists of a scintillator coupled to a streak camera and requires higher yields than the bang time system.

By comparing the experimental bang time from the nTD to that from the bang time system, a relative calibration can be obtained.

Using two direct drive shots with high enough yield to use nTD and the Bang Time detector, we obtain a calibration number of 29.703 ns for DD neutrons.

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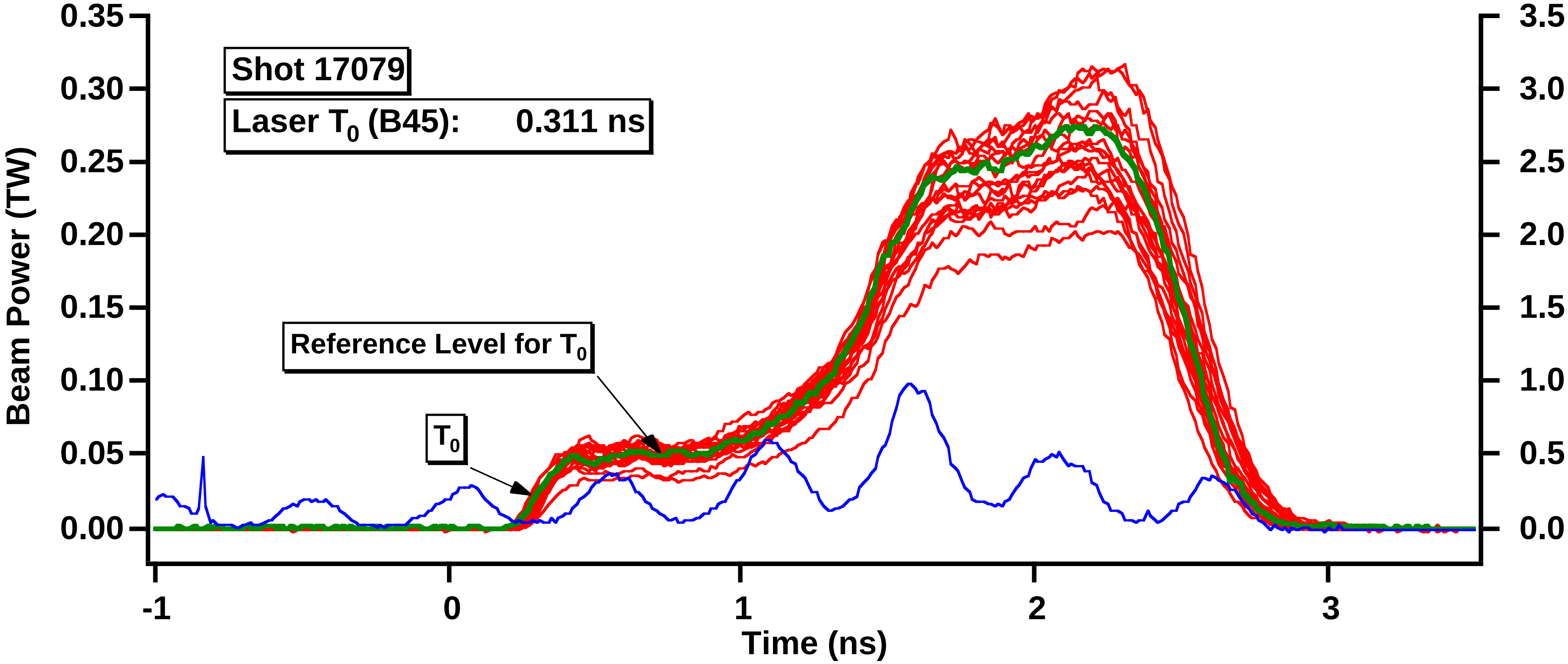
Example analysis: Using LLE-supplied P510 data, the position of the 50% point of the laser is found relative to the fiducial



In this case, the time is 0.311 ns.

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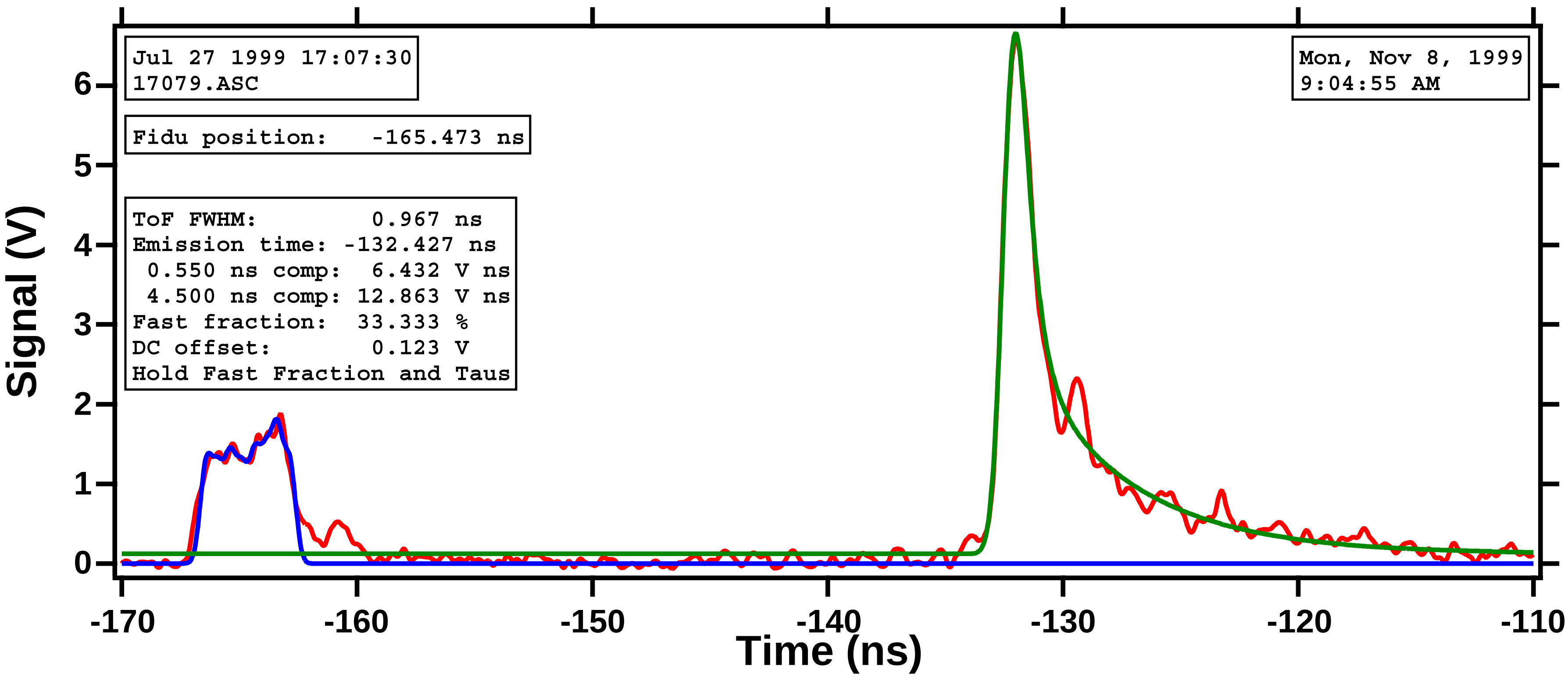
Example analysis: The position of the fiducial and the neutron pulse are then found on the digitizer data



The fidu To is at -165.473 ns

The neutron peak is at -132.437 ns

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From these numbers we can calculate a bang time

Neutron time:	**-132.437 ns**
Fidu time (on digitizer):	**-165.473 ns**
Difference (subtract to give):	**33.036 ns**
Laser T_o:	**0.311 ns**
Calibration number for DD neutrons from comparison to nTD:	**29.703 ns**
Bang time:	**3.022 ns**

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Some work remains to be done

- Obtain x-ray data with the system for timing calibration.
- Implement computer control of the system.
- Increase the throughput of the programmable attenuator for the 531 nm fiducial.
- Reduce the noise seen at shot time.
- Determine uncertainty in measurement.

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